



Probabilistic Structural Analysis in Steam Generators—Lessons Learned

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Steam Generator (SG) Tube Integrity (TI)

- TI is defined in each unit's Technical Specifications (TS)
 - **Structural** integrity
 - **Leakage** integrity
- **Performance-based TS/Framework** – describes desired outcomes, rather than prescriptive procedures on how to meet criteria
 - Must be quantitatively “**measureable**”
 - Must be “**tolerable**”


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Industry Guidelines for Assessing TI

- Industry has developed guidelines for assessing TI
 - Goal: ensure TI until next inspection
- Probabilistically, TI is met if the performance parameter is met with a probability of 0.95 with 50% confidence
 - **Structural Integrity** – worst-case degraded tube or SG
 - **Leakage Integrity** – worst-case SG

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Strategies for Combining Uncertainties in Industry Guidelines

There are different methods for assessing TI; method chosen based on need to increase accuracy and reduce conservatism

- Arithmetic (single tube)
 - Uncertainties taken at 95th percentile worst-case values
 - Simplest and most conservative
- Simplified Statistical (single tube)
 - Slightly more complicated and more realistic than the arithmetic method
- Monte Carlo: Simplified (single tube) or Fully Probabilistic (full bundle)
 - Combine uncertainties through repeated Monte Carlo simulations
 - Most complicated, most representative of flaw population

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Strategies for Combining Uncertainties in Industry Guidelines (continued)

- Although more conservative, arithmetic and simplified statistical methods are used more often than fully probabilistic methods
- Two scenarios where fully probabilistic methods are typically used:
 - Simplistic methods are overly conservative
 - Simplistic methods are no longer conservative


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Methods Approved by NRC

- NRC staff has only explicitly approved probabilistic methods for evaluating TI in a few specific cases
 - Generic Letter (GL) 95-05
- Although not explicitly evaluated/approved, NRC staff reviews the results of inspections and reports submitted by licensees as required by their TS.

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GL 95-05 (August 3, 1995)

- “Voltage-based Repair Criteria for Westinghouse Steam Generator Tubes Affected by Outside Diameter Stress Corrosion Cracking”
- Relates Non Destructive Evaluation (NDE) parameter (voltage) to an integrity parameter (burst and leakage)
- Methodology to calculate conditional burst probability to provide conservative assessment of tube structural integrity during a postulated Main Steam Line Break (MSLB) occurring at the End of Cycle (EOC)


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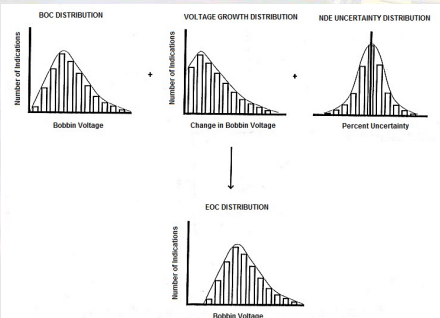
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Predicting the EOC Voltage Distribution




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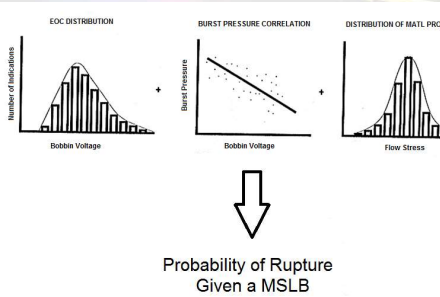
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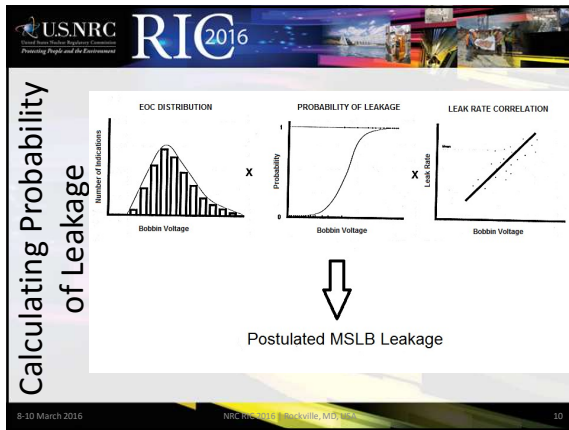
Calculating Probability of Rupture



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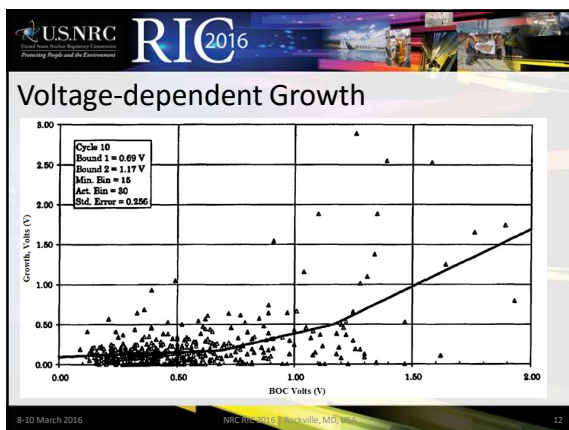


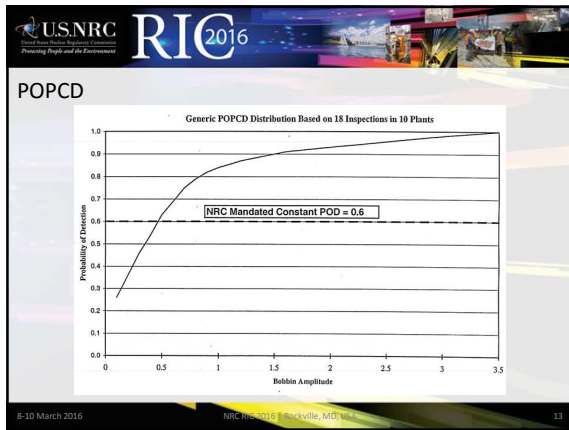
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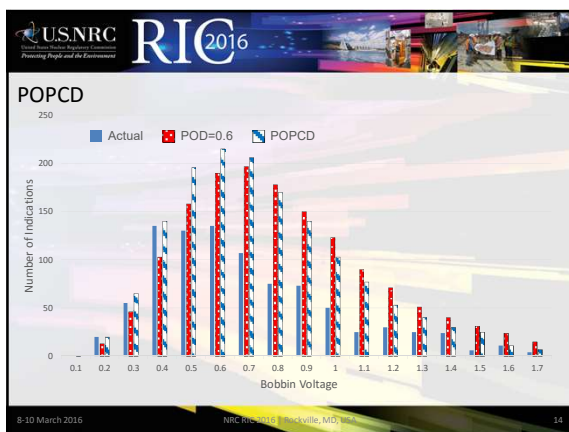
Lessons Learned

- With time, it became apparent that modifications to the methodology were needed
 - Methodology was overly conservative for some aspects and not conservative for others.
- Voltage-dependent growth
 - Some plants experienced growth rates that appeared to be dependent on the beginning of cycle (BOC) voltage.
- Probability of detection (POD) model determined to be very conservative
 - Development of Probability of Prior Cycle Detection (POPCD), which utilizes the ratio of indications reported at the prior inspection (cycle n) to the total indications found at the subsequent inspection (cycle n+1)

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Conclusions

- Based on operating experience, a phased approach for assessing integrity has been effective at ensuring TI.
- Operating experience also indicates it is important to compare projections and results so models can be verified and/or adjusted.

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